STAND
SHORTLEAF
DENSITY
AFFECTS
PINE
YIELD

IN MISSOURI

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SHORTLEAF PINE

This is the first in a series of three publications on the management of shortleaf pine in the Missouri Ozarks. The other two are: *Understory Hardwoods Retard Growth,* and *Two Methods of Thinning.*

The natural range of shortleaf pine in Missouri covers about 7 million acres in the east and south-central part of the Ozarks. The forest land here is characterized by rough topography and shallow, rocky, infertile soils. Summer droughts are common in spite of average annual precipitation in excess of 40 inches. As a result, some sites are too poor to produce high-quality hardwood timber. Many of these sites, however, if properly managed, could grow good crops of pine. We have prepared this series of publications to facilitate management of shortleaf pine on such sites in the Missouri Ozarks. The information presented represents the 10-year results of our pine studies.

The authors gratefully recognize the leadership of Dr. Franklin G. Liming in implementing the study upon which this manuscript is based. His efforts in shortleaf pine research in Missouri are now bearing results. Dr. Liming is currently on the staff of the Division of Timber Management Research, U.S. Forest Service, Washington, D.C.

IN MISSOURI

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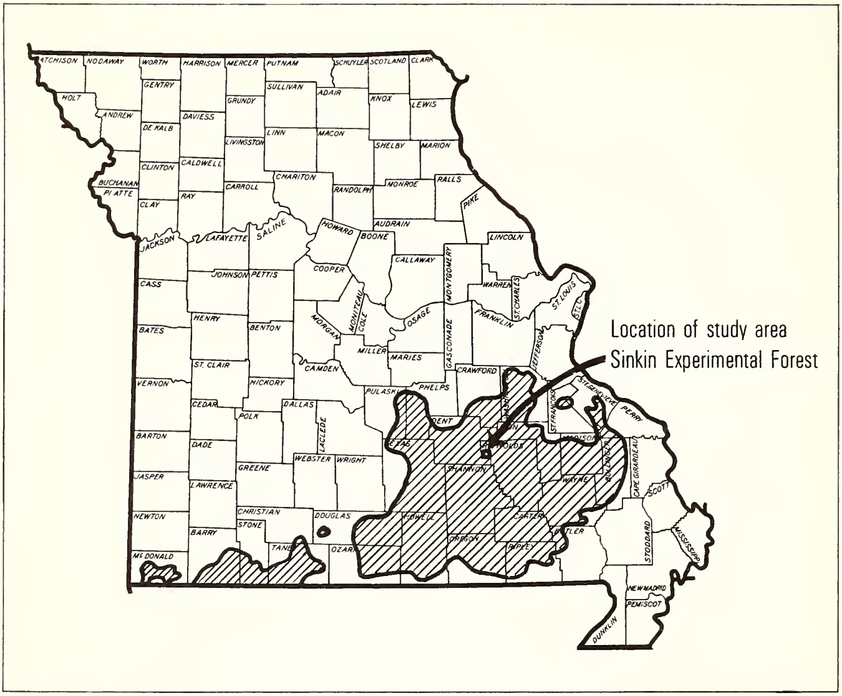

Range of Shortleaf Pine in Missouri

Shortleaf Pine in Missouri

STAND DENSITY AFFECTS YIELD

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A basic objective of timber management is the maximum production of high-quality wood in the shortest period of time. The forester controls quantity and quality of timber yield by manipulating stand density between two extremes. In understocked stands, the average tree may grow fast, but total growth per acre will be low because all growing space is not utilized. Tree quality also may suffer. Conversely, in overstocked stands trees die because of crowding. The ideal stocking lies somewhere between. The question is: Where? In order to find out for shortleaf pine *(Pinus echinata Mill.)* in Missouri, we are studying the growth and yield in young stands thinned to five different densities. Our 10-year results are reported here.

THE STUDY AREA

The study was conducted in a pine-oak stand on the Sinkin Experimental Forest, Dent County, Missouri. The stand is located on the tops and sides of two main ridges. Slope ranges from 4 to 30 percent. The soil is classified as Clarksville stony loam. Site index is 60 to 65, about average for shortleaf pine in Missouri.

The stand developed naturally after harvest of an oak-pine stand about 1918. Since 1933 this area has been a part of the Clark National Forest and has not been burned. Most hardwood trees in the stand were cut or girdled in 1934 and the pines were thinned from about 1,100 to 600 trees per acre (fig. 1).

This early thinning eliminated the poorest pine trees, removed most competing hardwoods, and left the better pine trees free to grow. By 1951, however, the need for another thinning was indicated by reduced diameter growth, complete crown closure, and the presence of many overtopped trees.

FIGURE 1. — In 1934, when the stand was 15 years old, it was thinned to about 600 trees per acre and most of the hardwood trees were cut.

Pine trees ranged in diameter from 1 to 12 inches, averaging 6.4 inches. Dominant and codominant trees were about 50 feet tall. Pine basal area averaged 138 square feet per acre.

Most hardwoods had resprouted by 1951 — when the stand was about 30 years old. The stands contained about 900 hardwoods per acre 0.6 inch d.b.h. and larger with a basal area of 14 square feet. In addition, there were about 3,500 smaller hardwood stems per acre. The most numerous understory species were black oak *(Quercus velutina* Lam.), white oak *(Q. alba* L.), sassafras *(Sassafras albidum* (Nutt.) Nees), and dogwood *(Cornus* L. spp.).

THE STUDY

The pines were selectively thinned to five different densities in 1951 and all hardwoods were cut or killed (table 1). The plan is to maintain these densities by periodic thinnings. Thinning frequency will depend on growth rate.

Table 1.--Pine stand conditions before and after the 1951 thinning

(Per acre)

Basal area in square feet		Number of trees		Cubic-foot volume 5 inches d.b.h. and larger[1]		Board-foot volume 7 inches d.b.h. and larger[2]	
Before	After	Before	After	Before	After	Before	After
129	50	563	163	2,120	900	5,570	3,025
139	70	624	225	2,190	1,230	5,750	4,080
141	90	571	281	2,260	1,535	6,520	5,090
130	110	565	408	2,005	1,785	4,970	4,740
138	138	597	597	2,290	2,290	6,160	6,160

1/ To a 3-inch top (d.i.b.).
2/ To a 5-inch top (d.i.b.) (International 1/4-inch rule).

Three plots were established for each density. Plots were square or nearly so, ½ acre in size, and surrounded by an isolation strip 30 feet wide. Stand densities established, in terms of basal area in square feet per acre, were 50, 70, 90, 110, and check (138).[1]

Basal area reductions in 1951 ranged from nearly two-thirds of the original stocking in the heaviest cuts (fig. 2) to less than one-sixth in the lightest. Selective thinning left the best possible trees; those with single, straight, well-formed boles that were free of large knots and other surface defects. Most crowns were full and vigorous. Live-crown length was from one-third to one-half of total tree height. In general, thinning left the largest trees consistent with good spacing.

Volume tables were constructed using taper measurements of representative trees cut in 1951 (tables 6 and 7, Appendix).

Initial hardwood control in 1951 consisted of cutting trees 0.6 inch d.b.h. and larger. In the summer of 1952 all hardwood foliage was sprayed with a mixture of 2,4,5-T in water at a rate of 3 pounds of acid equivalent per acre. Additional but less extensive foliage sprays were made in 1955 and 1959.

The pine stands were remeasured in the fall of 1960 and cut back in the spring of 1961 to the 1951 basal areas. The 1961 cutting left about 55 percent of the 1951 trees in the "50" and "70" plots and about 65 percent in the "90" and "110" plots. This removed almost all the poor-quality individuals in the thinned stands, leaving these stands in better condition than before.

Ice storms in 1954 and 1956 uprooted or severely damaged a few trees in nearly all stands. Other trees died because of overstocking. About 6 percent of the trees in the uncut stands died during the 10-year period. This mortality was limited to small trees that contained little usable volume.

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[1]For convenience these treatments are frequently referred to as "50," "70," etc.

FIGURE 2. — In 1951, thinning a 30-year-old shortleaf pine stand reduced basal area from 138 (top photo) to 50 square feet per acre (lower photo). All hardwoods were cut or killed.

10-YEAR RESULTS

Growth

As might be expected, growth *per tree* for the 10-year period decreased as stand density increased. In other words, the fewer the trees on an acre, the faster each tree grew. But in terms of cubic-foot volume growth *per acre,* the "70" plots produced the most and the check plots the least (table 2). These growth differences are not statistically significant, but they do indicate that there is no advantage in leaving more than 70 square feet of basal area when thinning pine stands of this age.

Ingrowth in 10 years ranged from 300 board feet per acre in the "50" plots to 1,120 feet in the uncut stands. More small trees were left in the denser stands where ingrowth will continue to be an important part of board-foot volume growth for several years.

Growth during these 10 years is not a reliable estimate of what can be expected during the remainder of the rotation, however. Height growth still is fairly rapid at this age, and merchantable height change is an important part of total growth. As height growth slows down with increasing age, most volume growth will be associated with increase in tree diameter.

Crown Growing Space

The degree of crown release directly affected subsequent tree growth. The crown growing space available to each of 25 sample trees in each plot was rated from zero to four depending on how many sides of the crown were free to grow after thinning. A side considered free to grow was 4 or more feet from adjacent crowns.

Trees released on three sides grew as fast as trees released on all four sides. And unreleased trees grew at the same rate as trees released on only one side. So it is concluded that trees should be released on two or three sides for best growth response.

Value of Product Yields

Although growth did not differ significantly among stand densities, the value of products cut did, with the highest value yields coming from the "70" density plots (table 3). In general, value of yields was higher in 1961 than in 1951, partly because of greater volumes cut, but chiefly because of improved market for poles and other products. Many of the trees cut in 1951 were large enough but too crooked to make poles; by 1961 most large

Table 2.--Production, growth, and yield (including mortality) from 1951 to 1961

(Per acre)

	Density treatment (basal area left)				
	50	70	90	110	Check
Basal area (square feet)					
Yield 1951	78.8	68.5	51.6	21.6	--
Left 1951	50.2	70.2	90.0	109.9	138.2
Growth 10 years 1/	32.7	38.5	37.2	36.3	34.9
Yield 10 years 1/	32.7	39.0	37.1	36.3	3.3
Left 1961	50.2	69.7	90.1	109.9	169.8
Total production 2/	161.7	177.2	178.8	167.8	173.1
Volume (Cubic feet) 3/					
Yield 1951	1,220	960	725	220	--
Left 1951	900	1,230	1,535	1,785	2,290
Growth 10 years 1/	855	990	930	955	810
Yield 10 years 1/	675	780	690	635	30
Left 1961	1,080	1,440	1,775	2,105	3,070
Total production 2/	2,975	3,180	3,190	2,960	3,100
Volume (board feet) 4/					
Yield 1951	2,545	1,670	1,430	230	--
Left 1951	3,025	4,080	5,090	4,740	6,160
Growth 10 years 1/	5,075	5,950	5,570	5,710	4,825
Yield 10 years 1/	2,915	3,290	2,690	1,715	50
Left 1961	5,185	6,740	7,970	8,735	10,935
Total production 2/	10,645	11,700	12,090	10,680	10,985
Number of trees					
Total trees	563	624	571	565	597
Cut 1951	400	399	290	157	--
Left 1951	163	225	281	408	597
Mortality	11	1	2	13	38
Cut 1961	64	93	98	127	--
Left 1961	88	131	181	268	559

1/ Includes mortality.
2/ Sum of 1951 and 1961 yields plus the stand left in 1961.
3/ Gross peeled volume in cubic feet to a 3-inch top (d.i.b.).
4/ Gross volume to a 5-inch top (d.i.b.) (International 1/4-inch rule).

trees met pole standards. In both 1951 and 1961 the value of poles was higher per unit of volume than that of saw logs or fenceposts.

Product quality in shortleaf pine is determined to a large extent by tree size. Standards for post and pole grades are based on minimum inside bark diameters and length; additional requirements of

Table 3.--Product and value yields per acre from 1951[1] and 1961[2] thinnings

Yields	Density treatment (basal area left) and year of thinning							
	50		70		90		110	
	1951	1961	1951	1961	1951	1961	1951	1961
Pine trees cut (5 inches d.b.h. and larger)								
Number	326	64	294	93	211	98	96	127
Average diameter (inches)	6.4	9.6	6.2	9.0	6.4	8.1	5.7	6.7
Posts								
Number	446	106	401	169	482	226	206	423
Average length (feet)	7.0	8.3	7.0	8.7	7.0	8.5	7.0	7.9
Poles								
Number	107	[3] 65	107	[3] 96	43	92	3	63
Average length (feet)	21.4	23.4	20.5	21.7	20.0	19.5	18.0	17.5
Saw logs								
Number	49	5	43	10	116	5	21	--
Volume (board feet)[4]	338	173	319	285	789	90	165	--
Value (dollars)[5]								
Each thinning	52	73	42	93	32	76	9	66
Total	125		135		108		75	

1/ Potential yield assuming a graded-pole market. All trees were actually sold as posts or saw logs but each saw-log tree was first scaled in terms of graded poles.

2/ Product yield, representing the actual 10-year growth.

3/ A few trees were cut into two poles.

4/ International 1/4-inch log rule.

5/ Actual stumpage value received from local commercial operator at the time of thinnings. Product prices represent the actual market conditions at that time of thinning and do not necessarily represent present conditions.

knot size, crook, sweep, and exterior defects must also be met. More large, high-quality trees were cut in 1951 in the low-density treatments ("50" and "70"), and trees in these plots also had the highest individual tree growth rates. Therefore, graded-product yields from the two thinnings were greatest from the low-density stands.

About 80 percent of the 1961 cut in the "50" and "70" stands consisted of poles or saw logs, while posts made up nearly 60 percent of the total yield in the "110" stands. The average value of trees cut in the latter stands was about half that of the trees in the "50" and "70" stands. These differences in unit value per tree will no doubt persist for many years.

The yields discussed here indicate the relative returns that can be expected from thinning managed pine stands of this age. The "50" stands are understocked for maximum production and the "110" and check stands now have too many trees. There are some indications that returns from the "90" stands will be about as good as those from the "70" stands within a few years.

Residual Stand Characteristics

Diameter distribution. — The 1961 cutting removed some trees of all sizes, but the largest trees usually were left (fig. 3). A normal distribution of diameter classes was maintained in all treatments. Average tree diameters after thinning ranged from 7.4 inches in the uncut plots to 10.2 inches in the "50" stands, about ½ inch larger than before the thinnings were made.

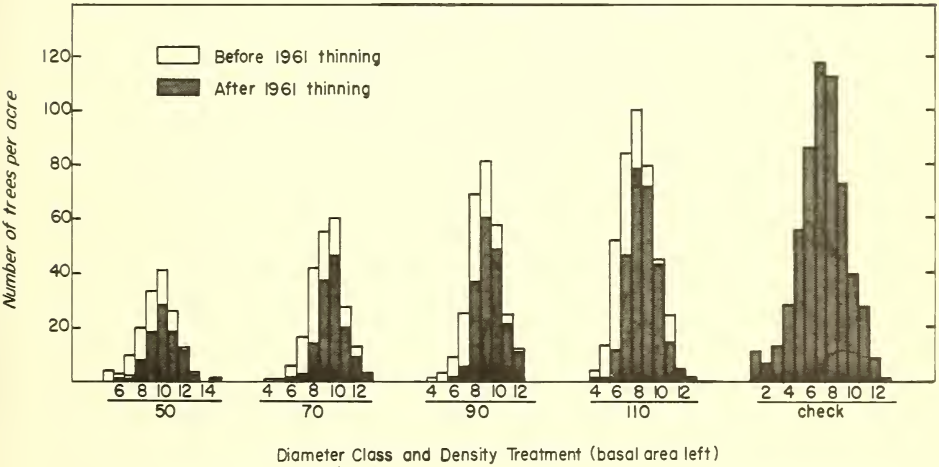

FIGURE 3. — The distribution of pine trees by diameter classes in each treatment. Shaded portions indicate stand structure after the 1961 thinning.

Total and merchantable height. — For the 10 years average height growth of trees was 8 to 10 feet regardless of treatment. Merchantable height increases during the period varied, however, being greatest for small trees in low-density stands (table 4). In the "50" and "70" stands, for example, increases in the merchantable heights of 6-inch trees were double those of the same size trees in uncut stands. Differences were nearly as great for all size

classes. The greater merchantable height increase in thinned stands resulted not from faster height growth but from decreased bole taper. With more growing space, the tree crowns increased in length, area, and density. The increased needle surface and better crown lighting per tree in turn caused faster bole growth, particularly in the area at the base of the crowns. This resulted in less bole taper and more usable volume per tree.

Table 4.--Merchantable height growth from 1951 to 1961 by treatment and diameter class

Density treatment (Basal area per acre left)	1951 Diameter class	Increase in merchantable height: 3-inch top (d.i.b.)	Increase in merchantable height: 5-inch top (d.i.b.)
	Inches	Feet	Feet
50	6	10	20
	8	8	14
	10	8	12
70	6	10	18
	8	9	14
	10	8	10
90	6	9	18
	8	8	14
	10	8	12
110	6	7	14
	8	6	12
	10	4	6
Check	6	5	9
	8	6	8
	10	4	7

Form class. — In these even-aged stands the largest trees have the best form, the fastest diameter growth rates, and made the greatest improvement in form during the last 10 years (table 5). Low-density stands contain relatively more large trees, and have a higher average form class than high-density stands. This difference is not expected to be permanent. The data indicate that when the present small trees in high-density plots attain similar diameters they will have essentially the same form. At this point in the life

of the stand, however, the better form of the low-density stands has affected total volume yield. This increase in merchantable height (or decrease in taper) resulted in higher dollar yield in a graded pole market.

Table 5.--Changes in form class associated with 1961 tree sizes and current diameter growth rates

Diameter (inches)		Girard form class1/ (percent)	
1961 d.b.h. class	10-Year increase	1961	10-Year increase
5	0.4	66	1.75
6	.8	69	2.25
7	1.2	72	3.00
8	1.6	74	3.60
9	2.0	76	4.25
10	2.4	77	4.85

1/ Girard form class is the ratio between the diameter inside bark at the top of the first 16-foot log to diameter outside bark at breast height.

CONCLUSIONS AND RECOMMENDATIONS

Although the total volume of wood produced was nearly independent of stand density, a clear choice of stand density to leave in thinnings can be made on the basis of actual yields. Yield is influenced by the size and kind of products that can be profitably sold.

Best overall growth and yield were from stands thinned at 30 years to 70 square feet of basal area per acre. Operable cuts are indicated at intervals of 8 to 10 years, as long as thinnings are needed. This cutting cycle makes it possible to maintain adequate crowns and growth rates on the better trees during the rotation.

Although thinnings will help maintain good diameter growth rates of individual trees, the current volume growth rates probably cannot be maintained indefinitely. They belong to a period when height growth still is rapid. After height growth begins to level off, volume growth will depend entirely on stem enlargement.

It is recommended that 30-year-old shortleaf pine stands be thinned to leave 70 square feet of basal area. The quality of trees left after the second thinning is at least as good in these stands as in any others. As the stands grow older, however, the best stocking density is expected to increase to about 90 square feet basal area per acre.

SUMMARY

Well-stocked, 30-year-old natural stands of shortleaf pine on average sites in Missouri were thinned in 1951 and again in 1961 to five densities: 50, 70, 90, 110, and 138 square feet of basal area per acre. All hardwoods were eliminated from the stands.

Total volume of wood produced during the 10 years was about the same regardless of stocking. At age 30, a basal area of about 70 square feet per acre was the minimum needed to make reasonably complete use of growing space. These stands grew faster than any other, and uncut stands grew the least but nearly as much as the 50-square-foot-basal-area stands.

Low-density stands yielded the highest quality and consequently highest value products. In 10 years, yields ranged from $66 per acre in high-density stands to $93 per acre in the stands cut to 70-square-feet basal area. The average value of individual trees cut in the 110-square-foot stands was about half that of trees cut in the 50- and 70-square-foot stands. Thinning 30-year-old pine stands to 70 square feet of basal area per acre resulted in the best overall growth and yield.

APPENDIX

Table 6.--Cubic-foot-volume table for natural 30- to 40-year-old shortleaf pine--gross peeled volume to a 3-inch top (d.i.b.)[1]

Regression equation: Volume = $-0.5389 + 0.0023\ D^2H$
Correlation coefficient (r) = .99

D.b.h. (Inches)	Cubic-foot volume when total height is 25	30	35	40	45	50	55	60	65	70	75	80
4	0.4	0.6	0.7	0.9	1.1							
5	.9	1.2	1.5	1.8	2.0	2.3						
6		1.9	2.4	2.8	3.2	3.6	4.0					
7		2.8	3.4	4.0	4.5	5.1	5.7					
8			4.6	5.3	6.1	6.8	7.6	8.3				
9			6.0	6.9	7.8	8.8	9.7	10.6	11.6			
10			7.5	8.7	9.8	11.0	12.1	13.3	14.4			
11				10.6	12.0	13.4	14.8	16.2	17.6	18.9		
12				12.7	14.4	16.0	17.7	19.3	21.0	22.6		
13				15.0	17.0	18.9	20.8	22.8	24.7	26.7	28.6	
14					19.7	22.0	24.3	26.5	28.8	31.0	33.3	
15					22.7	25.3	27.9	30.5	33.1	35.7	38.3	40.9
16						28.9	31.8	34.8	37.7	40.7	43.6	46.6
17						32.7	36.0	39.3	42.7	46.0	49.3	52.6

[1] These values were based on 30- to 50-year-old tree taper measurements ade in 1951. As a result of changes in form class associated with treatment, e 1961 volumes required adjustment. Form class increased from 2.4 to 4.9 ercent in 10 years. Basic data collected from 217 felled trees on or adjacent o study area.

Table 7.--Board-foot-volume table for natural 30- to 40-year-old shortleaf pine--gross volume to a 5-inch top (d.i.b.)[1]

Regression equation: Volume = $-15.24 + 0.013\ D^2H$
Correlation coefficient (r) = .98

D.b.h. (Inches)	Board-foot volume when total height is 35	40	45	50	55	60	65	70	75	80
6	1	3	6	8	10					
7	7	10	13	17	20					
8	14	18	22	26	30	35				
9	22	27	32	37	43	48	53			
10	30	37	43	50	56	63	69			
11		48	56	63	71	79	87	95		
12		60	69	78	88	97	106	116		
13		73	84	95	106	117	128	139	150	
14			99	112	125	138	150	163	176	
15			116	131	146	160	175	189	204	219
16				151	168	184	201	218	234	251
17				173	191	210	229	248	267	285

1/ These values were based on 30- to 50-year-old tree taper measurements made in 1951. As a result of changes in form class associated with treatment, the 1961 volumes required adjustment. Form class increased from 2.4 to 4.9 percent in 10 years. Basic data collected from 154 felled trees on or adjacent to study area. (International 1/4-inch log rule.)

THE AUTHORS

KENNETH A. BRINKMAN began his Forest Service career at the Central States Station in 1938. He soon moved to Mississippi with the Southern Forest Experiment Station, then to Arizona with the Southwestern Station, then to Alabama with the Southern Station again. Finally, in 1948, he returned to the Central States and worked in Iowa until 1955. Since then he has been at our Columbia, Missouri, field office. A lieutenant in the Coast Guard during World War II, Brinkman was commanding officer of a subchaser and later a tanker. Ken got his forestry training in his native state of Iowa, earning B.S. and M.S. degrees at Iowa State University. He is a silviculturist specializing in regeneration, woody-plant control, and conversion of low-quality oak stands.

NELSON F. ROGERS has been with the U.S. Forest Service for more than 30 years — 20 of them with the Central States Forest Experiment Station. Before beginning his research career he served on National Forests throughout eastern United States. Nelson is a graduate of the State University of New York College of Forestry. Although Rogers' primary responsibility is serving as Superintendent of the Station's Sinkin Experimental Forest near Salem, Missouri, his active participation in silvicultural research projects has resulted in more than a dozen publications.

SAMUEL F. GINGRICH began his Forest Service career in 1957 after 6 years as an instructor of forest mensuration and management at The Pennsylvania State University. Gingrich received his B.S. degree from Penn State in 1950 and his M.S. degree in 1954. He served 3 years in the Navy Air Corps during World War II. Sam is a member of Xi Sigma Pi and Gamma Sigma Delta, honor societies of forestry and agriculture, and the Society of American Foresters. He is Project Leader for the Station's research in forest mensuration.

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